FermiGrid and FermiCloud Update

ISGC 2012

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Fermilab Computing Facilities

Feynman Computing Center (FCC):
- FCC2 Computer Room
- FCC3 Computer Rooms
- High availability services – e.g. core network, email, etc.
- Tape Robotic Storage (3 x 10000 slot libraries)
- UPS & Standby Power Generation
- ARRA project: upgrade cooling and add HA computing room - completed

Grid Computing Center (GCC):
- 3 Computer Rooms – GCC-[A,B,C]
- Tape Robot Room – GCC-TRR
- High Density Computational Computing
- CMS, RUNII, Grid Farm batch worker nodes
- Lattice HPC nodes
- Tape Robotic Storage (4 x 10000 slot libraries)
- UPS & taps for portable generators

Lattice Computing Center (LCC):
- High Performance Computing (HPC)
- Accelerator Simulation, Cosmology nodes
- Systems for Integration & Development
- No UPS

US EPA Energy Star award for 2010 & 2011

Grid & Cloud Computing Department

Keith Chadwick (Department Head)
Gabriele Garzoglio (Associate Head)

Distributed Offline Computing Services

Gabriele Garzoglio (Leader)
David Dykstra
Tanya Levshina
Parag Mhashilkar
Marko Slyz
Douglas Strain

FermiGrid Services

Steven C. Timm (Leader)
Hyunwoo Kim (Visitor - KISTI)
Faarooq Lowe
Seo-Young Noh (Visitor – KISTI)
Neha Sharma
Daniel R. Yocum

FermiGrid

The Fermilab Campus Grid (FermiGrid) consists of the high throughput computing clusters at Fermilab together with the underlying highly available service infrastructure that enables these resources for the Grid

FermiGrid – Strategy & History

- In 2004, the Fermilab Computing Division undertook the strategy of placing all of its production resources in a Grid "meta-facility" infrastructure called FermiGrid.

- In April 2005, the first "core" FermiGrid services were deployed.

- In 2007, the FermiGrid-HA project was commissioned with the goal of delivering 99.999% core service availability (not including building or network outages).
  - In the first seven months of operation from November 2007 through June 2008, the measured core service availability was 99.997%.

- In 2011, the FermiGrid-HA2 project was commissioned with the goal of having the FermiGrid infrastructure being able to withstand significant building or network failures.
  - I'll be presenting the results of this work later in this presentation.

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FermiGrid – Goals of the Strategy

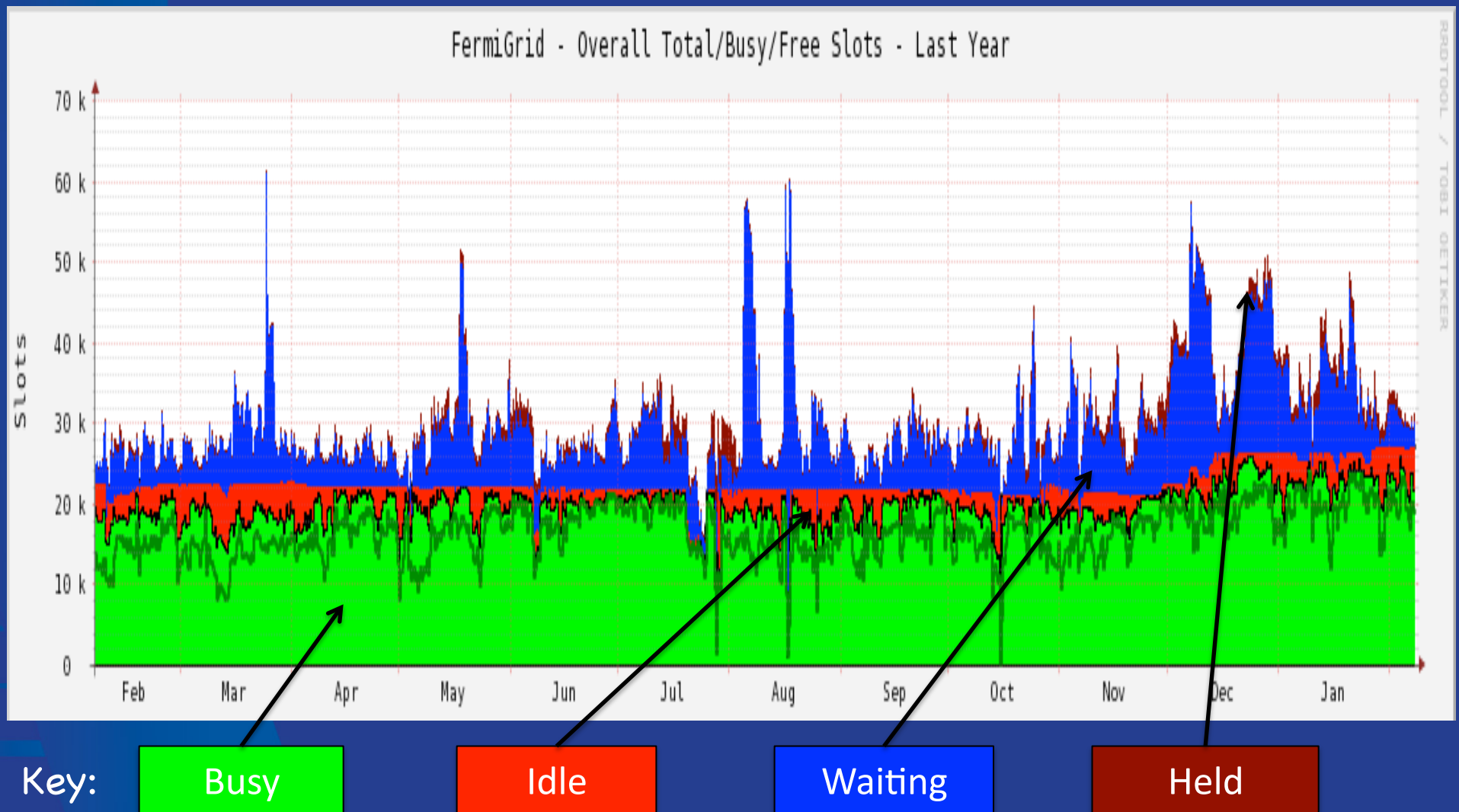The FermiGrid strategy was designed to allow Fermilab:

- to insure that the large experiments who currently have dedicated resources to have first priority usage of those resources that are purchased on their behalf.
- to allow opportunistic use of these dedicated resources, as well as other shared Farm and Analysis resources, by various Virtual Organizations (VO's) that participate in the Fermilab experimental program and by certain VOs that use the Open Science Grid (OSG).
- to optimise use of resources at Fermilab.
- to make a coherent way of putting Fermilab on the Open Science Grid.
- to save some effort and resources by implementing certain shared services and approaches.
- to work together more coherently to move all of our applications and services to run on the Grid.
- to better handle a transition from Run II to LHC in a time of shrinking budgets and possibly shrinking resources for Run II worldwide.
- to fully support Open Science Grid and the LHC Computing Grid and gain positive benefit from this emerging infrastructure in the US and Europe.
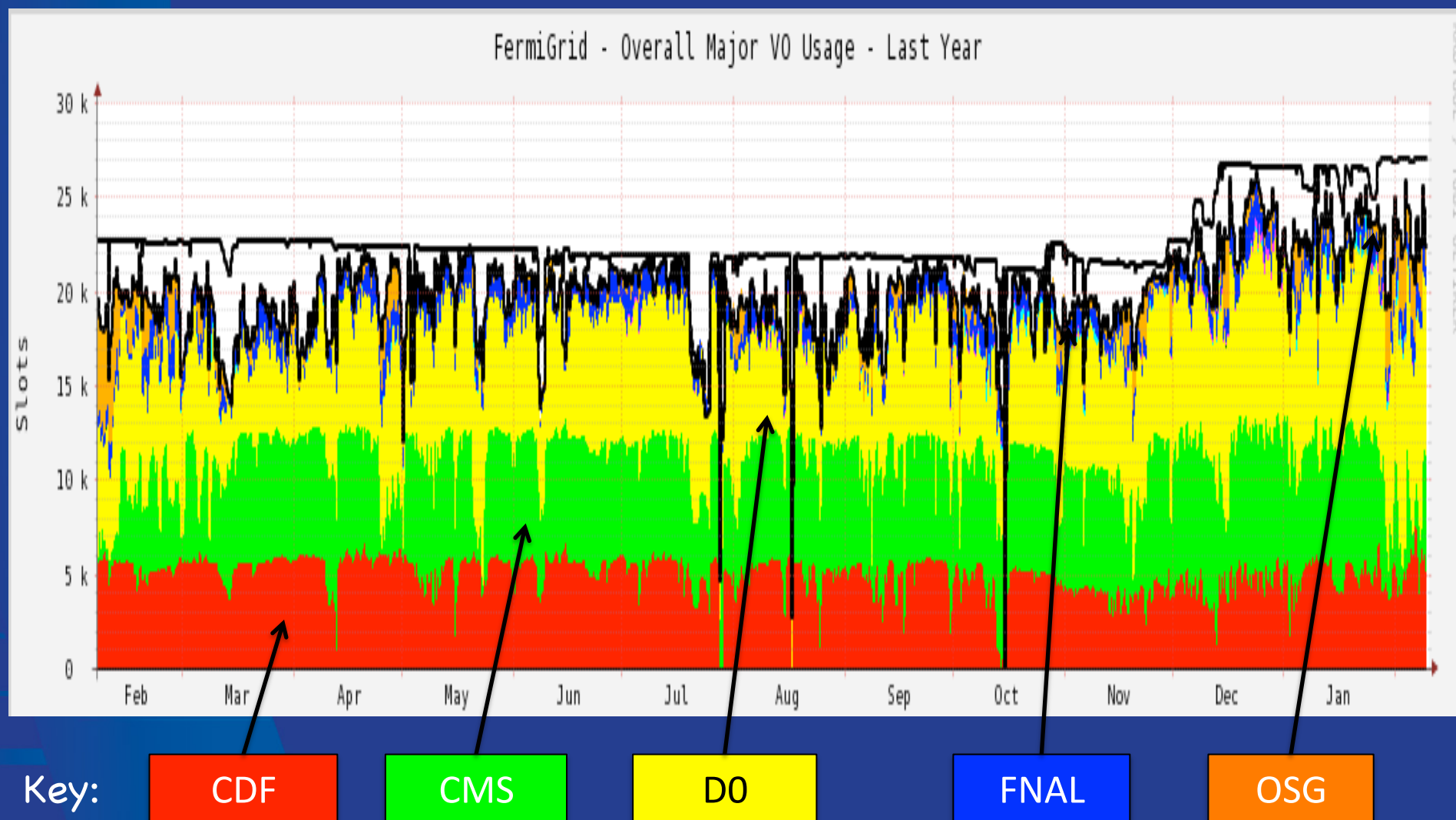
Current FermiGrid Statistics (as of February 2012)

Cluster(s)	Batch System	Job Slots	Raw Occupancy	Effective Utilization
CDF (Merged)	Condor	6,260	94.3	72.8
CMS T1	Condor	7,784	98.3	88.2
D0 (Merged)	PBS	8,242	80.3	59.7
GP Grid	Condor	4,898	83.5	73.2
_____		_____	_____	_____
Overall-Today		27,184	89.3	73.3

Slot = one CPU core that's assigned to a single user job (to first order),
Occupancy = % of Slots that are occupied by jobs,
Utilization = % CPU usage of occupied slots.

FermiGrid Overall Usage

FermiGrid - Overall Total/Busy/Free Slots - Last Year

Key: Busy | Idle | Waiting | Held

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FermiGrid – Usage By Community

FermiGrid - Overall Major VO Usage - Last Year
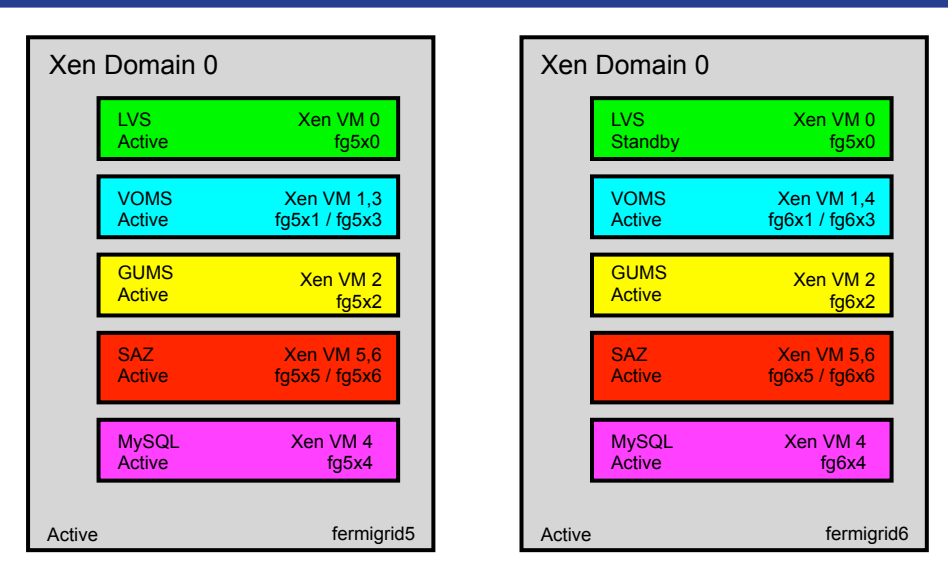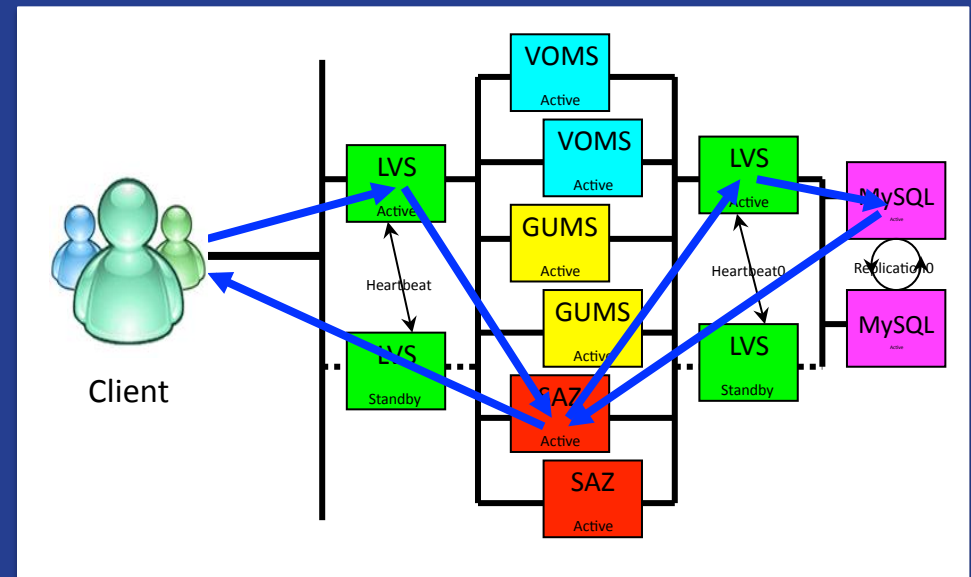
Key: CDF | CMS | D0 | FNAL | OSG

FermiGrid-HA – Service Redundancy (deployed in 2007)

FermiGrid-HA uses three key technologies:

- Linux Virtual Server (LVS),
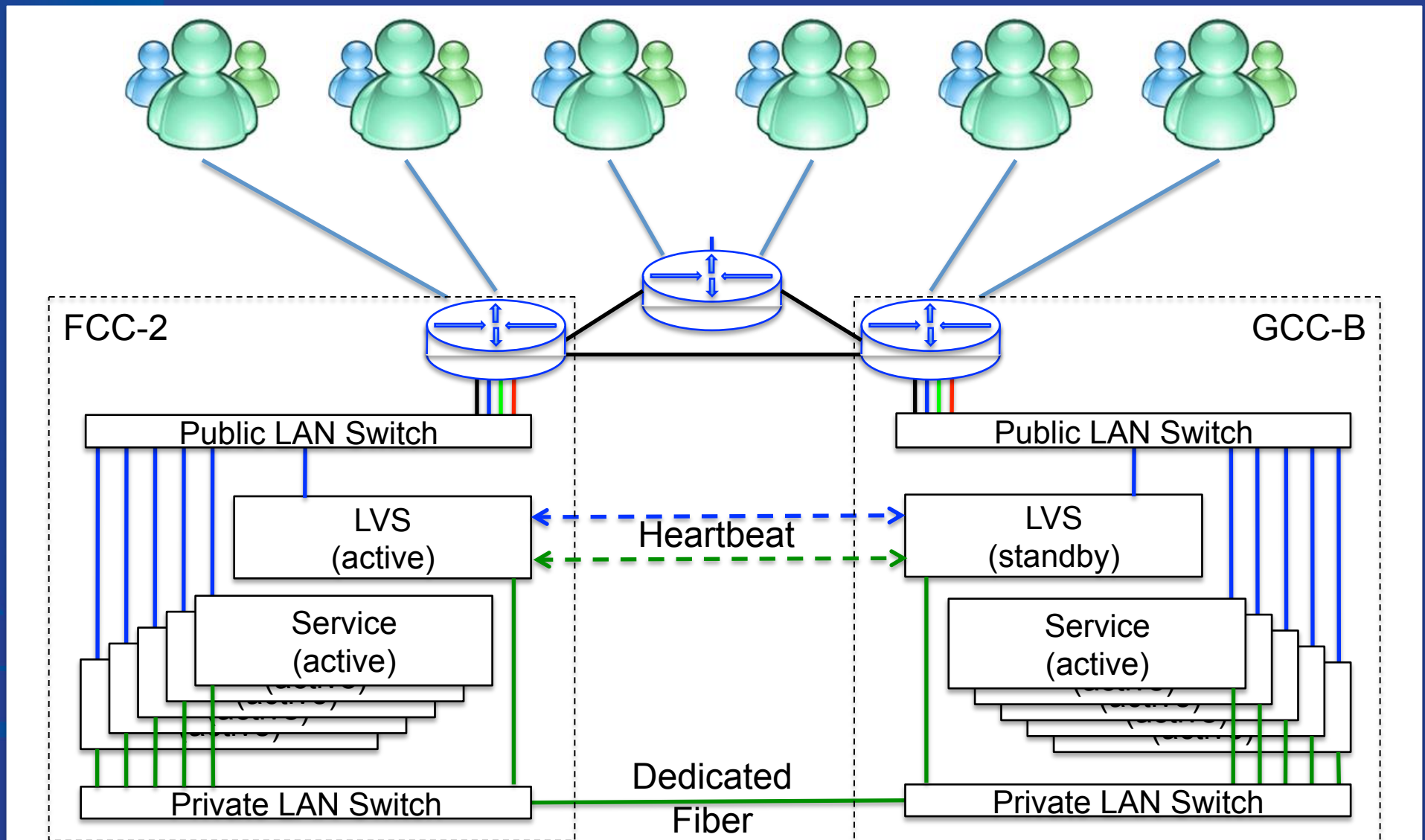- Xen Hypervisor,
- MySQL Circular Replication.

The goal for FermiGrid-HA is greater than 99.999% service availability (Not including building or network outages).
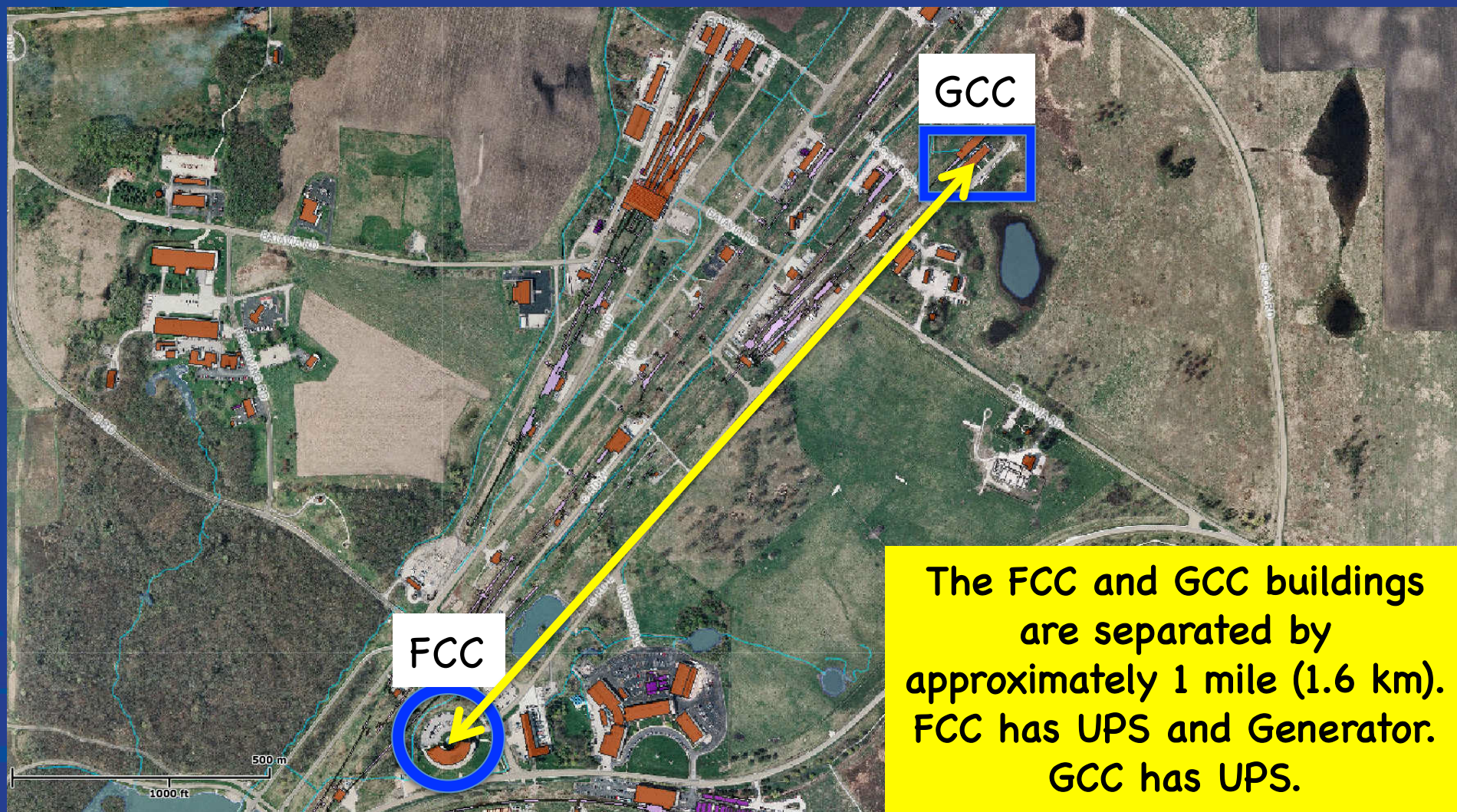
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What Environment Do We Operate In?

Risk	Mitigation
Service Failure	Redundant copies of Service (with service monitoring).
System Failure	Redundant copies of Service (on separate systems with service monitoring).
Network Failure	Redundant copies of Service (on separate systems with independent network connections and service monitoring).
Building Failure	Redundant copies of Service (on separate systems with independent network connections in separate buildings and service monitoring).

FermiGrid-HA – Deployed in 2007

FermiGrid-HA2 – Deployed in 2011

FermiGrid-HA2 – Network & Geographic Redundancy (2011)

FermiGrid-HA2 – Geographic Locations

GCC

FCC

The FCC and GCC buildings are separated by approximately 1 mile (1.6 km). FCC has UPS and Generator. GCC has UPS.

FermiGrid-HA2 Deployment

- The FermiGrid-HA2 software, hardware & physical reorganization was completed on Tuesday 7-Jun-2011 at ~1300.
  - Replicated critical services are hosted in two data centers (FCC-2 & GCC-B).
  - Non-critical services are split across the two data centers.

- The plan had been to utilize a scheduled power outage on 13-Aug-2011 for FCC2 to serve as the final acceptance test for the FermiGrid-HA2 project.
  - This power outage was later moved to 15-Oct-2011, and FemiGrid-HA2 functioned as designed for the scheduled power outage.

- Unfortunately, ~2 hours after the completion of the FermiGrid-HA2 reorganization, the GCC-B computer room suffered a major cooling outage.
  - All systems in GCC-B were shut down when the facilities personnel switched off the main electrical panel breakers.

- FermiGrid-HA2 functioned exactly as designed.
  - The critical services failed back to the remaining copy of the service on FCC-2.
  - The non-critical services went to reduced capacity.
  - When cooling and power were restored at ~1700, the second copy of the critical services in GCC-B transparently rejoined the service "pool", and the non-critical services in GCC-B resumed operation.

FermiGrid Service Availability (measured over the past year)

Service	Raw Availability	HA Configuration	Measured HA Availability	Minutes of Downtime
VOMS – VO Management Service	99. 667%	Active-Active	100.000%	0
GUMS – Grid User Mapping Service	99.663%	Active-Active	100.000%	0
SAZ – Site AuthoriZation Service	99.622%	Active-Active	100.000%	0
Squid – Web Cache	99.663%	Active-Active	100.000%	0
MyProxy – Grid Proxy Service	99.374%	Active-Standby	99.749%	1,320
ReSS – Resource Selection Service	99.779%	Active-Active	100.000%	0
Gratia – Fermilab and OSG Accounting	99.195%	Active-Standby	99.997%	60
MySQL Database	99.785%	Active-Active	100.000%	0

FermiGrid "Core" Service Metrics (measured over the past year)

Service	Calls per Hour Average / Peak	Calls per Day Average / Peak
VOMS – VO Management Service	84 / 175	984 / 2,969
GUMS – Grid User Mapping Service	17.3K / 114.1K	415K / 1.25M
SAZ – Site AuthoriZation Service	14.6K / 150.3K	350K / 1.23M
Squid – Web Cache	-not measured-	8.24M / 29.62M
MyProxy – Grid Proxy Service	719 / 1,449	12.0K / 26.5K

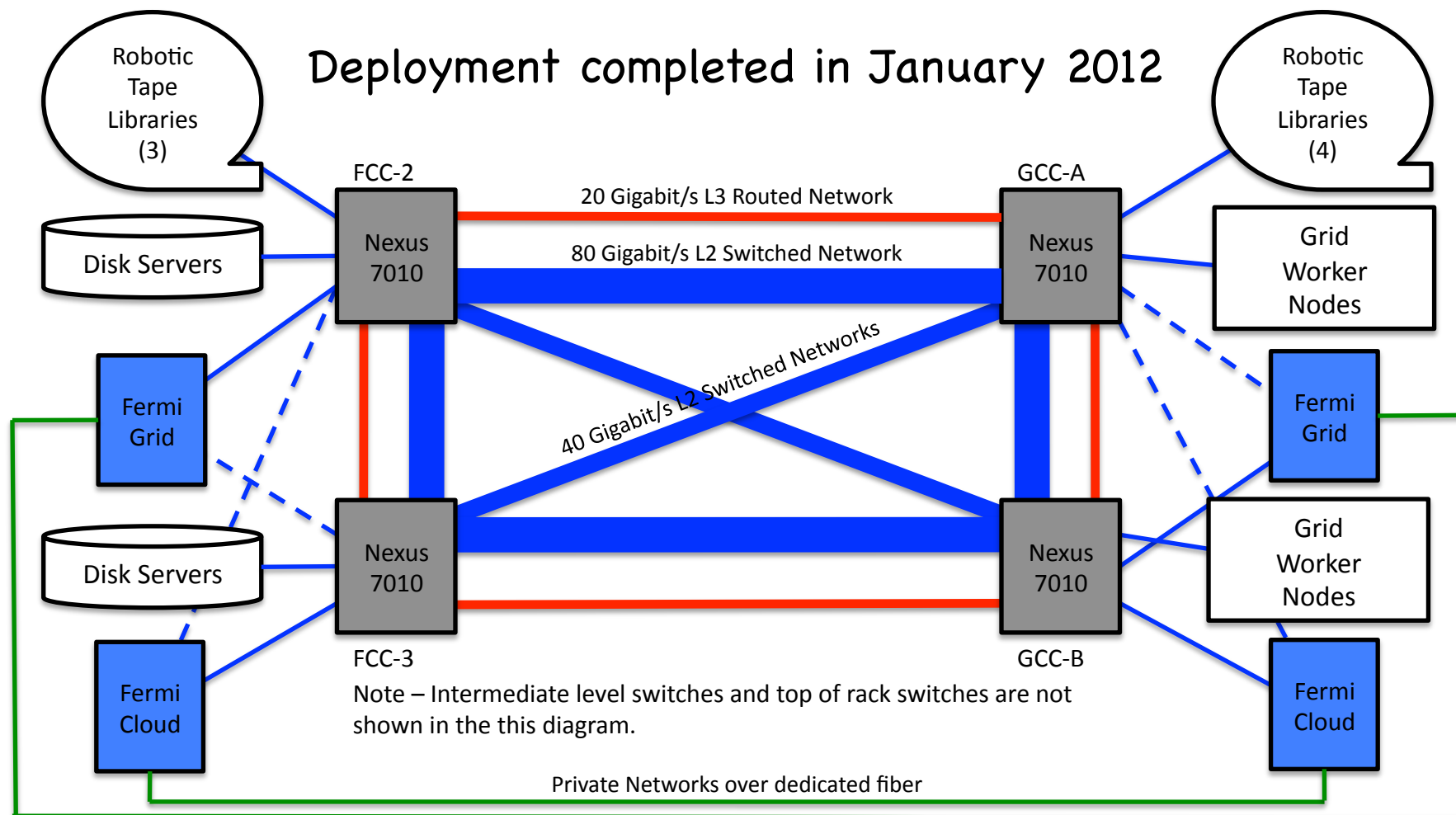🔷 **Fermilab**

FermiGrid Summary

- The FermiGrid-HA2 project to implement network & geographic redundancy proved itself two hours after completion!
  - And has been used several times since for both *scheduled* and *unscheduled* outages.

- The *measured* availability of the FermiGrid High Availability services is nothing less than extraordinary.
  - With the exception of MyProxy – Our MyProxy-HA service deployment using DRBD has proven to be extremely sensitive to Kernel version upgrades,
  - We have deployed additional policies, procedures and monitoring to work toward addressing the underlying issues on MyProxy service availability.

- FermiGrid (The Fermilab Campus Grid) is a *world class* infrastructure for scientific computing.
  - Across all three of the Fermilab research frontiers (Energy, Intensity and Cosmic),
  - FermiGrid stakeholders are routinely making opportunistic usage of other stakeholder resources across FermiGrid,
  - Together with opportunistic computing from the OSG and WLCG.

Network

Distributed Network "Core"
Provides Redundant Connectivity

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Distributed Network "Core" Provides Redundant Connectivity

FermiCloud

FermiCloud – Infrastructure as a Service (IaaS) Cloud Computing in support of the Fermilab Scientific Program

FermiCloud – Strategy, Goals & History

- As part of the FY2010 activities, the (then) Grid Facilities Department established a project to implement an initial "FermiCloud" capability.

- In a (very) broad brush, the mission of FermiCloud is:

  – To deploy a production quality Infrastructure as a Service (IaaS) Cloud Computing capability in support of the Fermilab Scientific Program.

  – To support additional IaaS, PaaS and SaaS Cloud Computing capabilities based on the FermiCloud infrastructure at Fermilab.

- This project is split over several overlapping phases.

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FermiCloud Phase 1

- Specify, acquire and deploy the FermiCloud hardware,

- Establish initial FermiCloud requirements and select the "best" open source cloud computing framework that best met these requirements (OpenNebula).

- Deploy capabilities to meet the needs of the stakeholders (JDEM analysis development, Grid Developers and Integration test stands, Storage/dCache Developers, LQCD testbed).

FermiCloud Phase 2

- Implement x509 based authentication (patches contributed back to OpenNebula project and are generally available in OpenNebula V3.2), perform secure contexualization of virtual machines at launch.

- Implement monitoring and accounting,

- Target "small" low-cpu-load servers such as Grid gatekeepers, forwarding nodes, small databases, monitoring, etc.

- Begin the hardware deployment of a distributed SAN,

- Investigate automated provisioning mechansims (puppet & cobbler).

FermiCloud Phase 3

- Select and deploy a true multi-user filesystem on top of a distributed & replicated SAN,

- Deploy 24x7 production services,

- Deploy puppet & cobbler,

- Live migration becomes important for this phase.

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FermiCloud – Hardware Specifications

Currently 23 systems split across FCC-3 and GCC-B:

- 2 x 2.67 GHz Intel "Westmere" 4 core CPU
  - Total 8 physical cores, potentially 16 cores with Hyper Threading (HT),
- 24 GBytes of memory (we are considering an upgrade to 48),
- 2 x 1GBit Ethernet interface (1 public, 1 private),
- 8 port Raid Controller,
- 2 x 300 GBytes of high speed local disk (15K RPM SAS),
- 6 x 2 TBytes = 12 TB raw of RAID SATA disk = ~10 TB formatted,
- InfiniBand SysConnect II DDR HBA,
- Brocade FibreChannel HBA (added in Fall 2011),
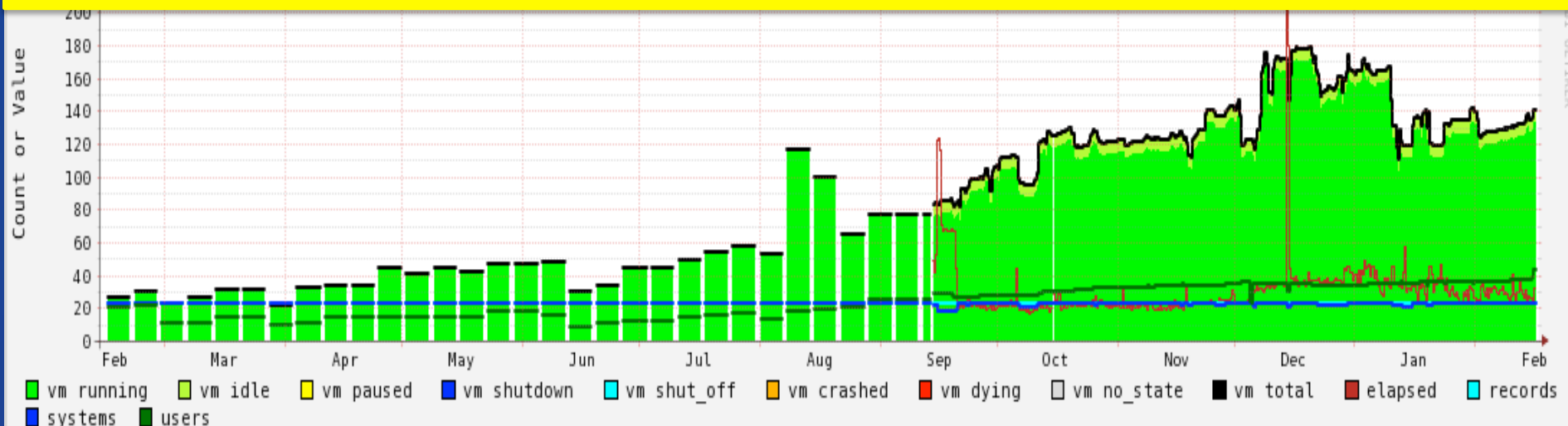- 2U SuperMicro chassis with redundant power supplies

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FermiCloud
Typical VM Specifications

- Unit:
  - 1 Virtual CPU [2.67 GHz "core" with Hyper Threading (HT)],
  - 2 GBytes of memory,
  - 10-20 GBytes of of SAN based "VM Image" storage,
  - Additional ~20-50 GBytes of "transient" local storage.

- Additional CPU "cores", memory and storage are available for "purchase":
  - Based on the (Draft) FermiCloud Economic Model,
  - Raw VM costs are competitive with Amazon EC2,
  - FermiCloud VMs can be custom configured per "client",
  - Access to Fermilab science datasets is much better than Amazon EC2.

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FermiCloud – Monitoring

- Temporary FermiCloud Usage Monitor:
  - http://www-fermicloud.fnal.gov/fermicloud-usage-data.html
  - Data collection dynamically "ping-pongs" across systems deployed in FCC and GCC to offer redundancy,
  - See plot on next page.

- FermiCloud Redundant Ganglia Servers:
  - http://fcl001k1.fnal.gov/ganglia/
  - http://fcl002k1.fnal.gov/ganglia/

- *Preliminary* RSV based monitoring pilot:
  - http://fermicloudrsv.fnal.gov/rsv

VM states as reported by "virsh list"

	Maximum	Average	Minimum	LastVal
records	23	23	23	23
systems	23	23	18	23
vm total	179	66	22	140
vm running	172	83	22	133
vm idle	7	7	6	7
vm paused	1	0	0	0
vm shutdown	0	0	0	0
vm shut off	0	0	0	0
vm crashed	0	0	0	0
vm dying	0	0	0	0
vm no state	0	0	0	0
users	43	24	9	43
elapsed	305	31	17	32

Note - vm states as reported by virsh list
Data for ferm...
Plot generate...   ...id0.fnal.gov

FermiCloud Target

FermiCloud Capacity	# of Units
Nominal (1 physical core = 1 VM)	184
50% over subscription	276
100% over subscription (1 HT core = 1 VM)	368
200% over subscription	552

Description of Virtual Machine States Reported by "virsh list" Command

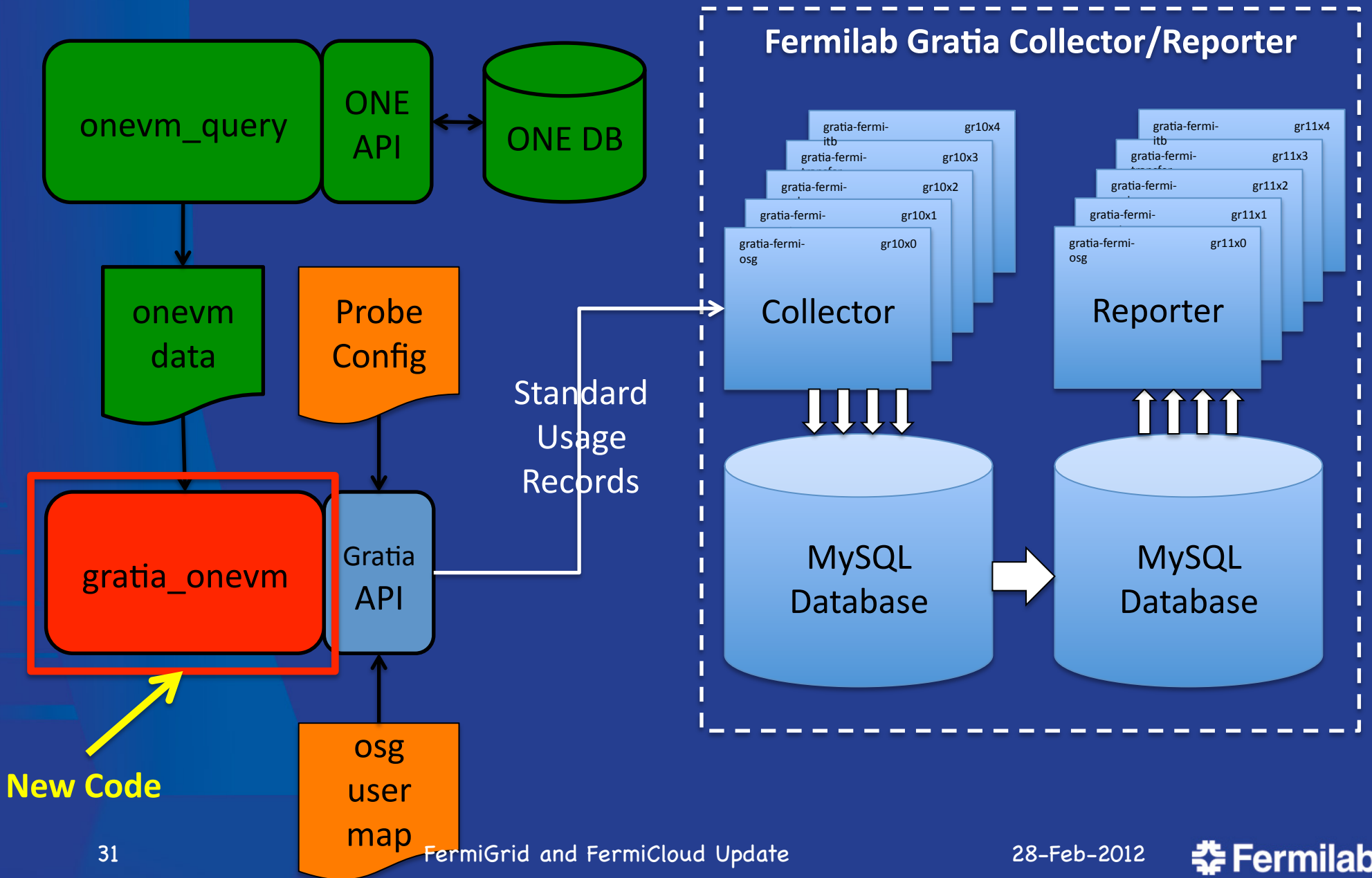| State	Description
running	The domain is currently running on a CPU. Note – KVM based VMs show up in this state even when they are "idle".
idle	The domain is idle, and not running or runnable. This can be caused because the domain is waiting on I/O (a traditional wait state) or has gone to sleep because there was nothing else for it to do. Note – Xen based VMs typically show up in this state even when they are "running".
paused	The domain has been paused, usually occurring through the administrator running virsh suspend. When in a paused state the domain will still consume allocated resources like memory, but will not be eligible for scheduling by the hypervisor.
shutdown	The domain is in the process of shutting down, i.e. the guest operating system has been notified and should be in the process of stopping its operations gracefully.
shut off	The domain has been shut down. When in a shut off state the domain does not consume resources.
crashed	The domain has crashed. Usually this state can only occur if the domain has been configured not to restart on crash.
dying	The domain is in process of dying, but hasn't completely shutdown or crashed.

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FermiCloud – Monitoring Requirements & Goals

- Need to monitor to assure that:
    - All hardware is available (both in FCC3 and GCC-B),
    - All necessary and required OpenNebula services are running,
    - All "24x7" & "9x5" virtual machines (VMs) are running,
    - If a building is "lost", then automatically relaunch "24x7" VMs on surviving infrastructure, then relaunch "9x5" VMs if there is sufficient remaining capacity,
    - Perform notification (via Service-Now) when exceptions are detected.

- We plan to replace the temporary monitoring with an infrastructure based on either Nagios or Zabbix during CY2012.
    - Possibly utilizing the OSG Resource Service Validation (RSV) scripts.
    - This work will likely be performed in collaboration with KISTI.

- A "stretch" goal of the monitoring project is to figure out how to identify really idle virtual machines.
    - Unfortunately, at the present time we cannot use the "virsh list" output, since actively running Xen based VMs are incorrectly labeled as "idle" and idle KVM based VMs are incorrectly labeled as "running".
    - In times of resource need, we want the ability to suspend or "shelve" the really idle VMs in order to free up resources for higher priority usage.
    - Shelving of "9x5" and "opportunistic" VMs will allow us to use FermiCloud resources for Grid worker node VMs during nights and weekends (this is part of the draft economic model).
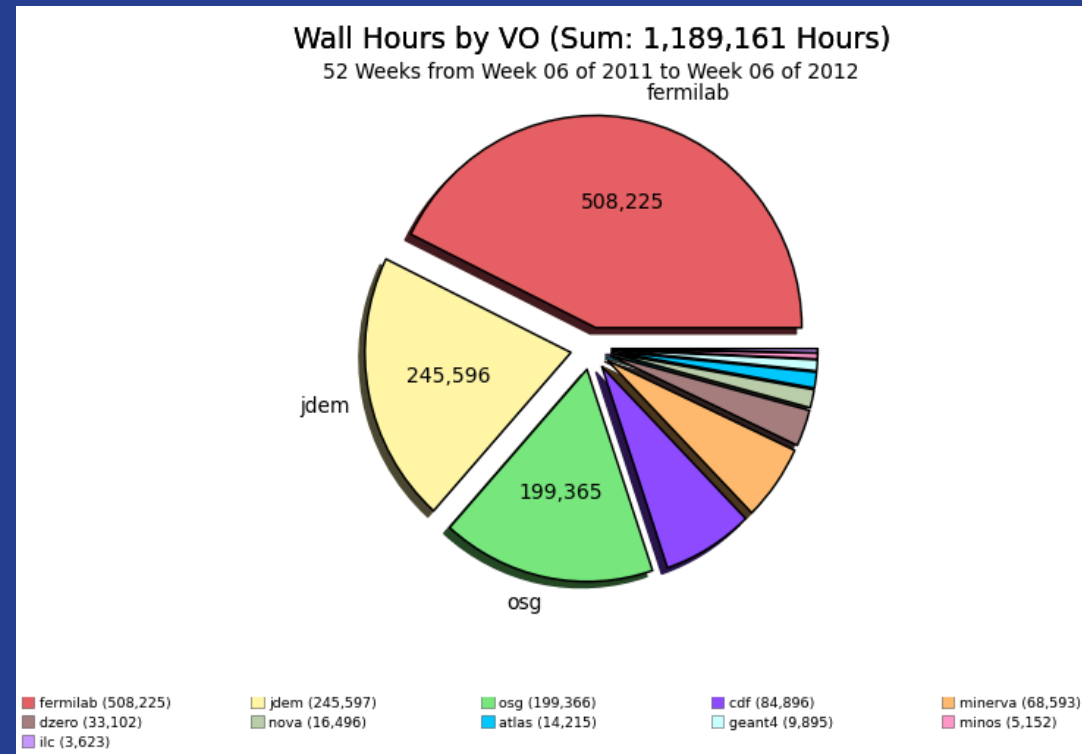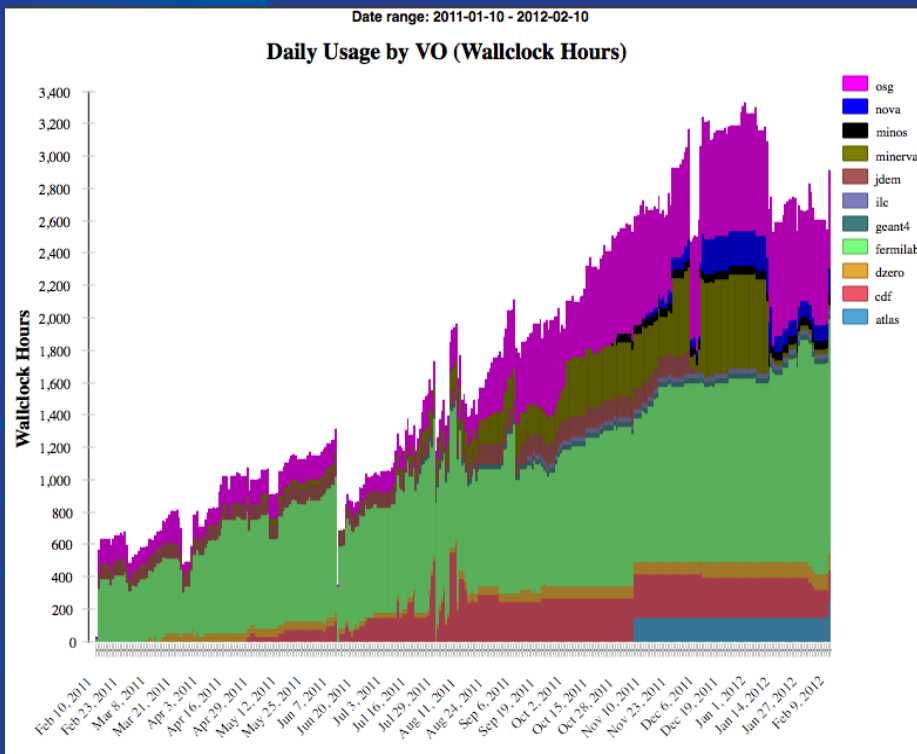
FermiCloud - Accounting

- Currently have two "probes" based on the Gratia accounting framework used by Fermilab and the Open Science Grid:
  - https://twiki.grid.iu.edu/bin/view/Accounting/WebHome

- Standard Process Accounting ("psacct") Probe:
  - Installed and runs within the virtual machine image,
  - Reports to standard gratia-fermi-psacct.fnal.gov.

- Open Nebula Gratia Accounting Probe:
  - Runs on the OpenNebula management node and collects data from ONE logs, emits standard Gratia usage records,
  - Reports to the "virtualization" Gratia collector,
  - The "virtualization" Gratia collector runs existing standard Gratia collector software (no development was required),
  - The development of the Open Nebula Gratia accounting probe was performed by Tanya Levshina and Parag Mhashilkar.

- Additional Gratia accounting probes could be developed:
  - Commercial – OracleVM, VMware, ---
  - Open Source – Nimbus, Eucalyptus, OpenStack, ...

Open Nebula Gratia Accounting Probe

onevm_query

ONE API

ONE DB

onevm data

Probe Config

gratia_onevm

New Code

Gratia API

osg user map

Standard Usage Records

Fermilab Gratia Collector/Reporter

gratia-fermi-itb — gr10x4
gratia-fermi-transfer — gr10x3
gratia-fermi- — gr10x2
gratia-fermi- — gr10x1
gratia-fermi-osg — gr10x0

Collector

gratia-fermi-itb — gr11x4
gratia-fermi-transfer — gr11x3
gratia-fermi- — gr11x2
gratia-fermi- — gr11x1
gratia-fermi-osg — gr11x0

Reporter

MySQL Database

MySQL Database

FermiGrid and FermiCloud Update

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FermiCloud – Gratia Accounting Reports

Here are the *preliminary* results of "replaying" the previous year of the OpenNebula "OneVM" data into the new accounting probe:

Date range: 2011-01-10 - 2012-02-10
Daily Usage by VO (Wallclock Hours)

Wall Hours by VO (Sum: 1,189,161 Hours)
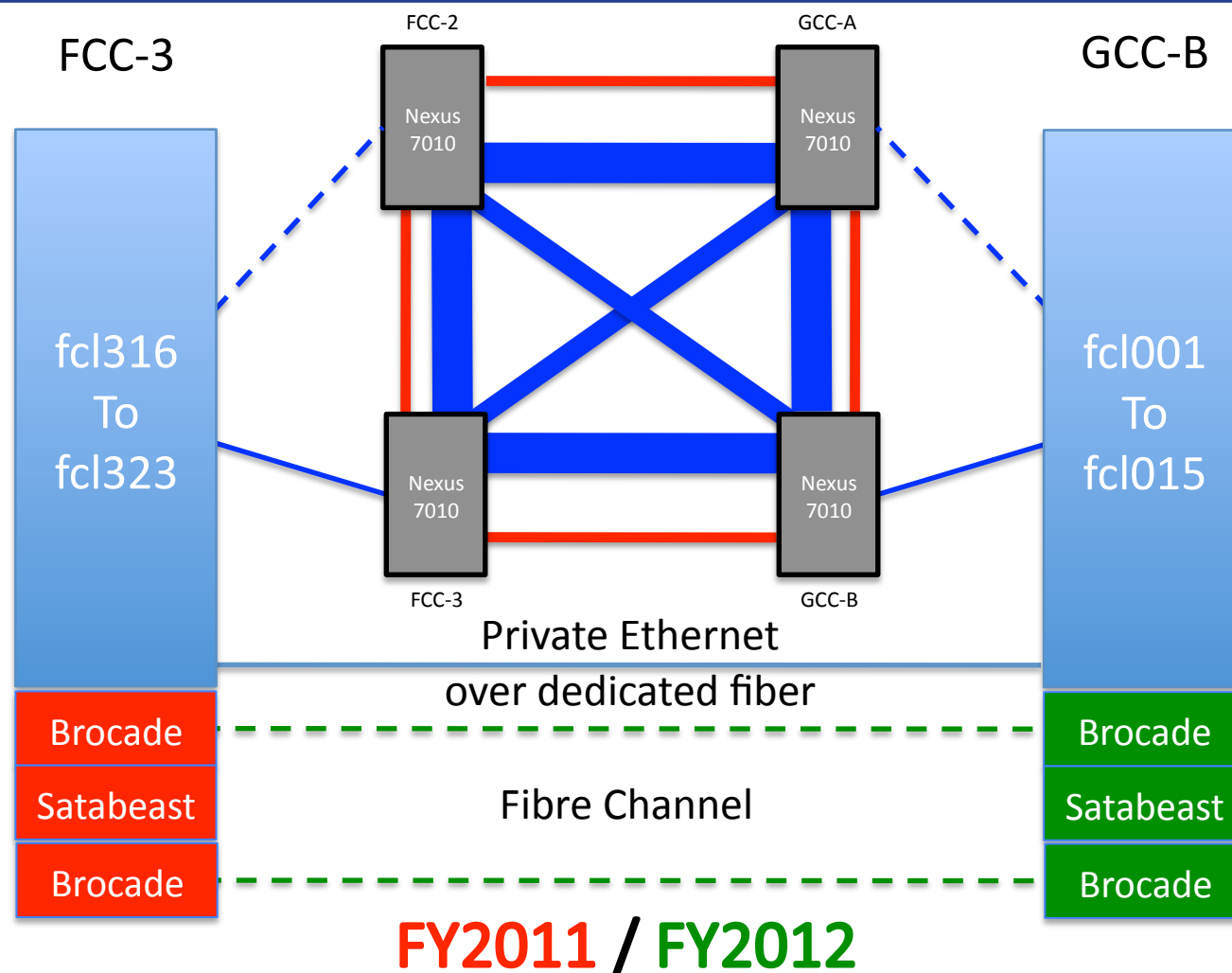52 Weeks from Week 06 of 2011 to Week 06 of 2012
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vCluster

- Deployable on demand virtual cluster using hybrid cloud computing resources.
    - Head nodes launched on virtual machines within the FermiCloud private cloud.
    - Worker nodes launched on virtual machines within the Amazon EC2 public cloud.

- Work performed by Dr. Seo-Young Noh (KISTI).
    - See his talk on Friday 2-Mar-2012 for more details.

MPI on FermiCloud (Note 1)

| Configuration	#Host Systems	#VM/host	#CPU	Total Physical CPU	HPL Benchmark (Gflops)
Bare Metal without pinning	2	--	8	16	13.9
Bare Metal with pinning (Note 2)	2	--	8	16	24.5
VM without pinning (Notes 2,3)	2	8	1 vCPU	16	8.2
VM with pinning (Notes 2,3)	2	8	1 vCPU	16	17.5
VM+SRIOV with pinning (Notes 2,4)	2	7	2 vCPU	14	23.6

Notes: (1) Work performed by Dr. Hyunwoo Kim of KISTI in collaboration with Dr. Steven Timm of Fermilab.
(2) Process/Virtual Machine "pinned" to CPU and associated NUMA memory via use of numactl.
(3) Software Bridged Virtual Network using IP over IB (seen by Virtual Machine as a virtual Ethernet).
(4) SRIOV driver presents native InfiniBand to virtual machine(s), 2nd virtual CPU is required to start SRIOV, but is only a virtual CPU, not an actual physical CPU.

FermiCloud – Network & SAN "Today"

FCC-3

fcl316
To
fcl323

Brocade

Satabeast

Brocade

FCC-2

Nexus 7010

GCC-A

Nexus 7010

FCC-3

Nexus 7010

GCC-B

Nexus 7010

Private Ethernet
over dedicated fiber

Fibre Channel

GCC-B

fcl001
To
fcl015

Brocade

Satabeast

Brocade

FY2011 / FY2012

Note – Dashed Lines = Waiting for Equipment or Fiber

FermiCloud – Network & SAN (Possible Future – FY2013/2014)

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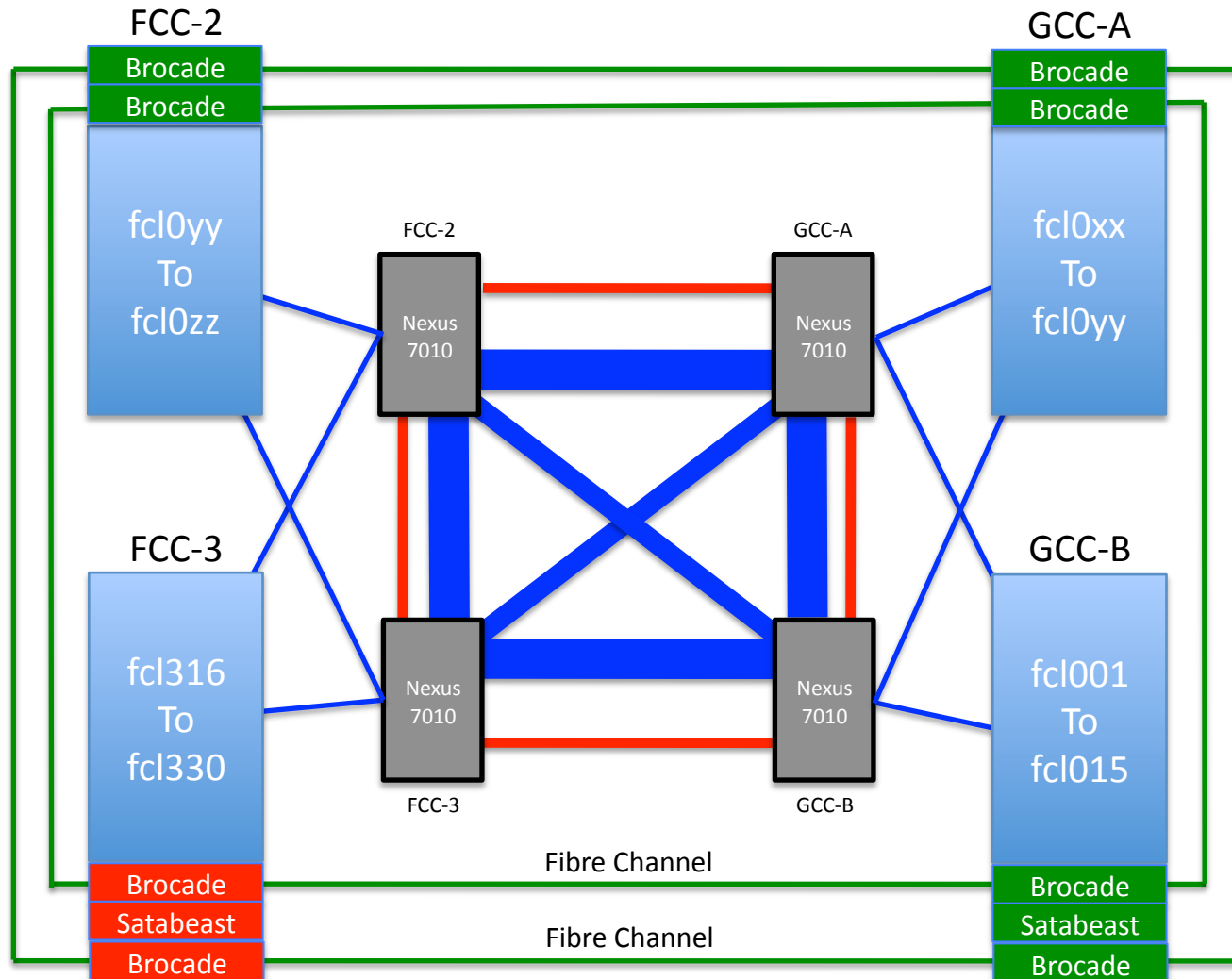
FermiCloud – Support for Science (direct and indirect)

- FermiCloud resources are routinely being used by Grid middleware developers and integrators as well as CDF, D0 and the Cosmic and Intensity Frontiers.

- FermiCloud resources were used to perform a detailed analysis of filesystem performance for Grid applications (See talk on Thursday 1-Mar-2012).

- FermiCloud resources were used to determine the optimal service configurations for the XACML AuthZ profile (See talk on Wednesday 29-Feb-2012).

- FermiCloud resources are currently being used to examine NFS v4 performance and will shortly be used to explore the implications of IPv6 for Grid and Cloud applications and middleware.

- FermiCloud resources are being used by the OSG Software team to "re-factor" the OSG software distribution from a pacman based distribution to an RPM based distribution.

- Production services have been deployed on FermiCloud, including:
  - Specialized GridFTP virtual machines for the Intensity Frontier experiments,
  - NFS Administration virtual machines to allow Intensity Frontier experiments to perform file ownership management of their BlueArc volumes.

FermiCloud Summary

- The existing (temporary) FermiCloud usage monitoring shows that the peak FermiCloud usage is ~100% of the nominal capacity and ~50% of the expected oversubscription capacity.

- The FermiCloud collaboration with KISTI has leveraged the resources and expertise of both institutions to achieve significant benefits.

- FermiCloud has plans to implement both monitoring and accounting by extension of existing tools in CY2012.

- Using SRIOV drivers on FermiCloud virtual machines, MPI performance has been demonstrated to be **>96%** of the native "bare metal" performance.
  - Note that this HPL benchmark performance measurement was accomplished using **2 fewer** physical CPUs than the corresponding "bare metal" performance measurement!

- FermiCloud personnel are working to implement a SAN storage deployment that will offer a true multi-user filesystem on top of a distributed & replicated SAN.

- Science is directly and indirectly benefiting from FermiCloud.

Overall Summary

- FermiGrid continues to be a world class infrastructure for scientific computing:
  - Energy Frontier Experiments – CDF, D0 & CMS,
  - Intensity Frontier (neutrino) and Cosmic Frontier (astrophysics) experiments,
  - Opportunistic Computing (OSG and WLCG Virtual Organizations).

- FermiCloud operates at the forefront of delivering cloud computing capabilities to support physics research:
  - By starting small, developing a list of requirements, building on existing Grid knowledge and infrastructure to address those requirements, FermiCloud has managed to deliver an Infrastructure as a Service cloud computing capability that supports science at Fermilab.
  - The Open Science Grid software team is using FermiCloud resources to support their RPM "refactoring".

- None of this could have been accomplished without:
  - The excellent support from other departments of the Fermilab Computing Sector – including Computing Facilities, Site Networking, and Logistics.
  - The excellent collaboration with the open source communities – especially Scientific Linux and OpenNebula,
  - As well as the excellent collaboration and contributions from KISTI.

Thank You!

Any Questions?

Extra Slides

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FermiCloud vs. Magellan

FermiCloud	Magellan
Bottom up requirements and design.	Top down requirements and mission.
Funded out of existing budget ($230K+$128K).	Funded via ARRA ($32M).
Multi phase project, with each phase building on knowledge gained during previous phases.	Fixed term project without ongoing funding.
Evaluated available open source cloud computing frameworks (Eucalyptus, Nimbus, OpenNebula) against requirements and selected OpenNebula. We plan to "circle back" and evaluate OpenStack this year.	Spent a lot of time trying to get the open source version of Eucalyptus to work at scale, eventually switched to a combination of Nimbus and OpenStack late in the project.
Approached cloud computing from a Grid and high throughput computing (HTC) perspective.	Approached cloud computing from a high performance computing (HPC) perspective.
Significant prior experience delivering production Grid services via open source virtualization (Xen and KVM).	Unclear.
Have SRIOV drivers for InfiniBand.	Did not have SRIOV drivers for InfiniBand before the end of the project.
Actively sought collaboration (OpenNebula, KISTI).	Project was sited at NERSC and Argonne.